

CLAIMS**WE CLAIM:**

1. A fluid mixing device for mixing a first injection fluid and a second injection fluid, the fluid mixing device comprising:
 - a first fluid inlet configured to conduct the first injection fluid in a first direction, the first fluid inlet having a first redirecting surface;
 - a second fluid inlet configured to conduct the second injection fluid in a second direction, the second fluid inlet having a second redirecting surface;
 - a mixing chamber in fluid communication with the first fluid inlet and the second fluid inlet and having a third redirecting surface, the mixing chamber configured to mix the first injection fluid and the second injection fluid; and
 - an outlet port in fluid communication with the mixing chamber and distal to the first fluid inlet and the second fluid inlet,wherein the first redirecting surface is configured to redirect the first injection fluid in a first different direction from the first direction to enter the mixing chamber along the first different direction, and the second redirecting surface is configured to redirect the second injection fluid in a second different direction from the second direction to enter the mixing chamber along the second different direction, wherein the first different direction and the second different direction are selected so that the first injection fluid and the second injection fluid contact the third redirecting surface of the mixing chamber to turbulently mix the first injection fluid and second injection fluid in the mixing chamber, and
 - wherein a mixture of the first injection fluid and the second injection fluid exits the fluid mixing device through the outlet port.
2. The fluid mixing device of claim 1, further comprising at least one of a first check valve in the first fluid inlet; and a second check valve in the second fluid inlet.
3. The fluid mixing device of claim 2, wherein the first fluid inlet and the second fluid inlet have a non-circular cross-sectional shape, and wherein the first check valve and the second check valve have a circular cross-sectional shape.

4. The fluid mixing device of any one of claims 1 to 3, wherein the first fluid inlet and the second fluid inlet have a first inlet port and a second inlet port, respectively, wherein the first redirecting surface and second redirecting surface are positioned distally relative to the first inlet port and second inlet port, respectively, and wherein the third redirecting surface is positioned proximally relative to the outlet port, the first redirecting surface, and the second redirecting surface.
5. The fluid mixing device of any one of claims 1 to 4, wherein the mixing chamber further comprises a first inlet, wherein the first inlet of the mixing chamber is distal to the third redirecting surface, and wherein the first redirecting surface is positioned distal to the first fluid inlet and at least partially faces the first inlet to the mixing chamber.
6. The fluid mixing device of any one of claims 1 to 5, wherein the mixing chamber further comprises a second inlet, wherein the second inlet of the mixing chamber is distal to the third redirecting surface, and wherein the second redirecting surface is positioned distal to the second fluid inlet and at least partially faces the second inlet to the mixing chamber.
7. The fluid mixing device of any one of claims 1 to 6, wherein at least one of the first redirecting surface and the second redirecting surface is substantially concave and has a radius of curvature greater than or equal to 90° .
8. The fluid mixing device of any one of claims 1 to 6, wherein at least one of the first redirecting surface and the second redirecting surface is substantially concave and has a radius of curvature greater than or equal to 150° .
9. The fluid mixing device of any of claims 1 to 8, wherein the third redirecting surface has a substantially concave-shaped surface facing the outlet port.
10. The fluid mixing device of claim 9, wherein the concave-shaped surface has a radius of curvature of greater than or equal to 90° .
11. The fluid mixing device of claim 9, wherein the concave-shaped surface has a radius of curvature of greater than or equal to 150° .

12. The fluid mixing device of any one of claims 2 to 11, wherein the first check valve has a first end in engagement with a first inlet port on the first fluid inlet and a second end in engagement with a first stop element proximal to the first redirecting surface, wherein the second check valve has a first end in engagement with a second inlet port on the second fluid inlet and a second end in engagement with a second stop element proximal to the second redirecting surface, and wherein the first check valve and the second check valve are reversibly compressible between the first end and the second end in response to first fluid pressure of the first injection fluid flowing through the first inlet port and a second fluid pressure of the second injection fluid flowing through the second fluid port, respectively.

13. The fluid mixing device of claim any one of claims 1 to 12, wherein the first inlet port and the second inlet port have a tapered end surface.

14. The fluid mixing device of any one of claims 1 to 13, wherein the outlet port has an axis parallel to an axis of the first fluid inlet and an axis of the second fluid inlet.

15. The fluid mixing device of claim 14, wherein the axis of the outlet port extends between the axis of the first fluid inlet and the axis of the second fluid inlet.

16. The fluid mixing device of any one of claims 1 to 15, wherein each of the first redirecting surface and the second redirecting surface are concave-shaped and face a direction of fluid flow of the first injection fluid in the first fluid inlet and the second injection fluid in the second fluid inlet, respectively.

17. The fluid mixing device of any one of claims 1 to 16, wherein at least one of the first fluid inlet, the second fluid inlet, and the outlet port has an at least partially helical-shaped rifling on at least a portion of an inner surface of the at least one of the first fluid inlet, the second fluid inlet, and the outlet port for creating a corresponding fluid vortex for at least one of the first injection fluid, the second injection fluid, and the mixture of the first injection fluid and the second injection fluid.

18. The fluid mixing device of any one of claims 1 to 17, wherein the outlet port has at least one baffle member or mixing member disposed in an inner surface thereof.

19. The fluid mixing device of any one of claims 1 to 18, wherein the outlet port further comprises a pressure isolation valve integrated therewith.

20. The fluid mixing device of claim 19, wherein the pressure isolation valve comprises a housing having a first lumen in fluid communication with the outlet port, a second lumen configured for connecting to a pressure transducer, and a valve member between the first lumen and the second lumen, wherein the valve member is configured for isolating the second lumen from the outlet port during a fluid injection procedure.

21. A fluid delivery tube set for delivering fluid from a fluid injector to a patient, the fluid delivery tube set comprising:

- a first inlet tube configured to deliver a first injection fluid;

- a second inlet tube configured to deliver a second injection fluid;

- an outlet tube configured to deliver a mixture of the first injection fluid and the second injection fluid to a patient; and

- a fluid mixing device comprising:

- a first fluid inlet coupled to the first inlet tube and configured to conduct the first injection fluid in a first direction, the first fluid inlet having a first redirecting surface;

- a second fluid inlet coupled to the second inlet tube and configured to conduct the second injection fluid in second direction, the second fluid inlet having a second redirecting surface;

- a mixing chamber in fluid communication with the first fluid inlet and the second fluid inlet and having a third redirecting surface, the mixing chamber configured to mix the first injection fluid and the second fluid; and

- an outlet port coupled to the outlet tube and in fluid communication with the mixing chamber,

- wherein the first redirecting surface is configured to redirect the first injection fluid in a first different direction from the first direction to enter the mixing chamber along the first different direction, and the second redirecting surface is configured to redirect the second injection fluid in a second different direction from the second direction to enter the mixing

chamber along the second different direction, wherein the first different direction and the second different direction are selected so that the first injection fluid and the second injection fluid contact the third redirecting surface of the mixing chamber to turbulently mix the first injection fluid and second injection fluid together in the mixing chamber, and

wherein a mixture of the first injection fluid and the second injection fluid exits the fluid mixing device via the outlet port.

22. The fluid delivery tube set of claim 21, further comprising at least one of a first check valve in the first fluid inlet; and a second check valve in the second fluid inlet.

23. The fluid delivery tube set of claim 21 or 22, wherein the first fluid inlet and the second fluid inlet have a first inlet port and a second inlet port, respectively, wherein the first redirecting surface and second redirecting surface are positioned distally relative to the first inlet port and second inlet port, respectively, and wherein the third redirecting surface is positioned proximally relative to the outlet port, the first redirecting surface, and the second redirecting surface.

24. The fluid delivery tube set of any one of claims 21 to 23, wherein the mixing chamber further comprises a first inlet, wherein the first inlet of the mixing chamber is distal to the third redirecting surface, and wherein the first redirecting surface is positioned distal to the first fluid inlet and at least partially faces the first inlet to the mixing chamber.

25. The fluid delivery tube set of any one of claims 21 to 24, wherein the mixing chamber further comprises a second inlet, wherein the second inlet of the mixing chamber is distal to the third redirecting surface, and wherein the second redirecting surface is positioned distal to the second fluid inlet and at least partially faces the second inlet to the mixing chamber.

26. The fluid delivery tube set of any one of claims 21 to 25, wherein at least one of the first redirecting surface and the second redirecting surface is substantially concave and has a radius of curvature greater than or equal to 90°.

27. The fluid delivery tube set of any of claims 21 to 26, wherein the third redirecting surface has a substantially concave-shaped surface facing the outlet port.

28. The fluid delivery tube set of claim 27, wherein the concave-shaped surface has a radius of curvature of greater than or equal to 90° .

29. The fluid delivery tube set of any one of claims 21 to 28, wherein the outlet port has an axis parallel to an axis of the first fluid inlet and an axis of the second fluid inlet.

30. The fluid delivery tube set of claim 29, wherein the axis of the outlet port extends between the axis of the first fluid inlet and the axis of the second fluid inlet.

31. The fluid delivery tube set of any one of claims 21 to 30, wherein each of the first redirecting surface and the second redirecting surface are concave-shaped and face a direction of fluid flow of the first injection fluid in the first fluid inlet and the second injection fluid in the second fluid inlet, respectively.

32. The fluid delivery tube set of any one of claims 21 to 31, wherein the outlet port further comprises a pressure isolation valve integrated therewith.

33. The fluid delivery tube set of any of claims 21 to 32, further comprising a connector element on an exterior or an interior of at least one of the first fluid inlet, the second fluid inlet, and the outlet port.

34. A method for turbulently mixing a first injection fluid and a second injection fluid to form a substantially homogeneous mixture of the first injection fluid and the second injection fluid, the method comprising:

contacting a fluid flow of the first injection fluid with a first concave redirecting surface associated with a first fluid inlet;

redirecting the fluid flow of the first injection fluid to a first different direction, wherein the first different direction flows at an angle ranging from 90° - 175° from a fluid flow direction of the first injection fluid and towards a third concave redirecting surface in a mixing chamber;

contacting a fluid flow of the second injection fluid with a second concave redirecting surface associated with a second fluid inlet;

redirecting the fluid flow of the second injection fluid to a second different direction, wherein the second different direction flows at an angle ranging from 90-175° from a fluid flow direction of the second injection fluid and towards the third concave redirecting surface in the mixing chamber;

turbulently mixing the first injection fluid and the second injection fluid in the mixing chamber upon contact of the first injection fluid and the second injection fluid with the third concave redirecting surface to form a mixture of the first injection fluid and the second injection fluid; and

redirecting the mixture of the first injection fluid and the second injection fluid through an outlet port of the mixing chamber.